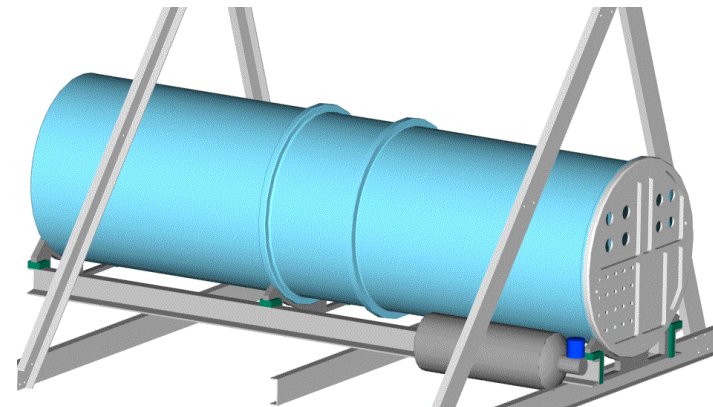
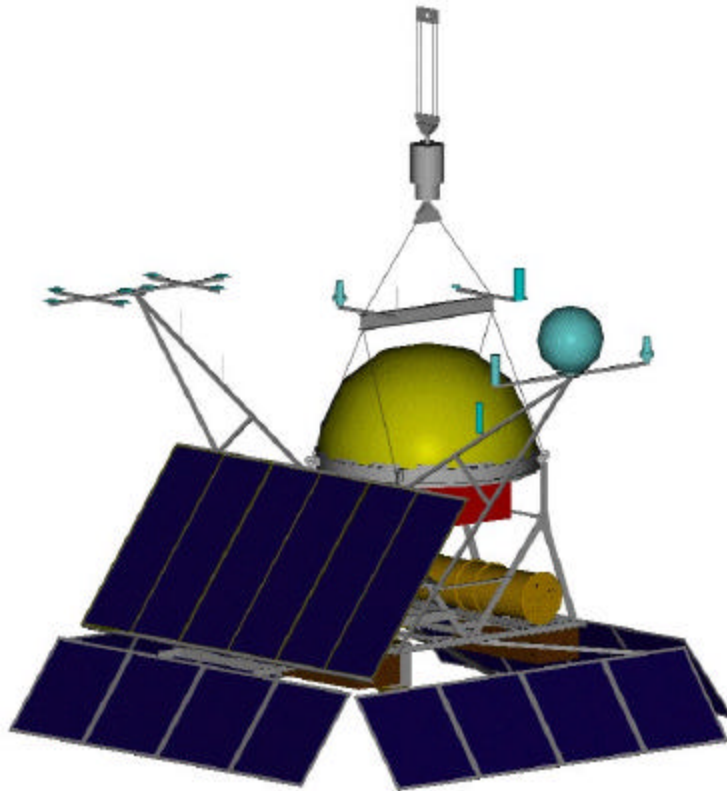
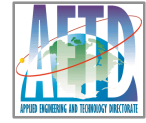
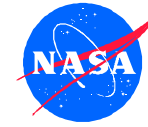


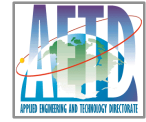
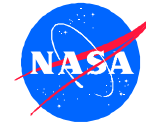
# *Enclosures & Gas Makeup*

---



# *Enclosures & Gas Makeup*

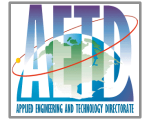
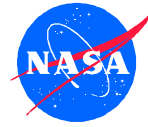
---



- **Enclosures**
  - Design To Requirements
  - Functional Requirements
  - Verification Matrix
  - Enclosure Design
  - Structural Analysis
  - Design Validation Testing
- **Gas Makeup System**
- **Risk Assessment & Mitigation**
- **Documentation**
- **Integration Testing**
- **Schedule**

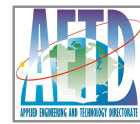
# *Enclosures*

---

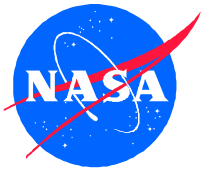


- **Design to Requirements Document**
  - No Requirements defined for Enclosures
- **Functional and Performance Requirements**
  - Provide thermal environment for components.
  - Provide pressure environment for hard drives.
  - Structural
    - Design to 10G vertical axis load, 5G @ 45°, and 5G horizontal load.
    - Ground impact protection.
    - Environment protection.

# Verification Matrix



|            | <u>DESCRIPTION</u>            | <u>METHOD</u>         | <u>STAGE</u>  |
|------------|-------------------------------|-----------------------|---------------|
| <b>1.0</b> | <b>Environment Compliance</b> |                       |               |
| 1.1        | Thermal Design & Layout       | Analysis, Thermal     | Development   |
| 1.2        | Thermal Performance           | Thermal Test          | Development   |
|            |                               | Thermal Vacuum Test   | Qualification |
|            |                               | Test Flight 2000      | Qualification |
| 1.3        | Pressure Performance          | Thermal Pressure Test | Development   |
|            |                               | Thermal Vacuum Test   | Qualification |
|            |                               | Test Flight 2000      | Qualification |
| <b>2.0</b> | <b>Structural</b>             |                       |               |
| 2.1        | Design                        | Analysis, Structural  | Development   |
| 2.2        | Fabrication                   | Inspection            | Development   |
| 2.3        | Hardware Validation           | Test Flight 2000      | Qualification |



**ULDB  
Mech.  
Systems  
Design  
Review**

**3.9  
Enclosures  
and  
Gas Makeup**

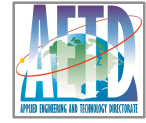
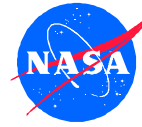
Bob Ray  
Code 546.w  
July 10, 2000

## *Enclosure Design*

- Command Data Module
- Hard Drive Enclosure
- Flight Computer Enclosure

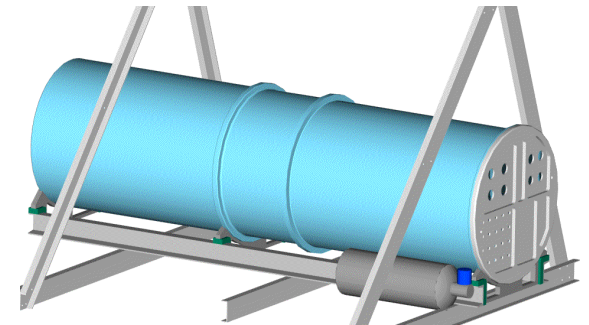
# *CDM - Command /Data Module*

---

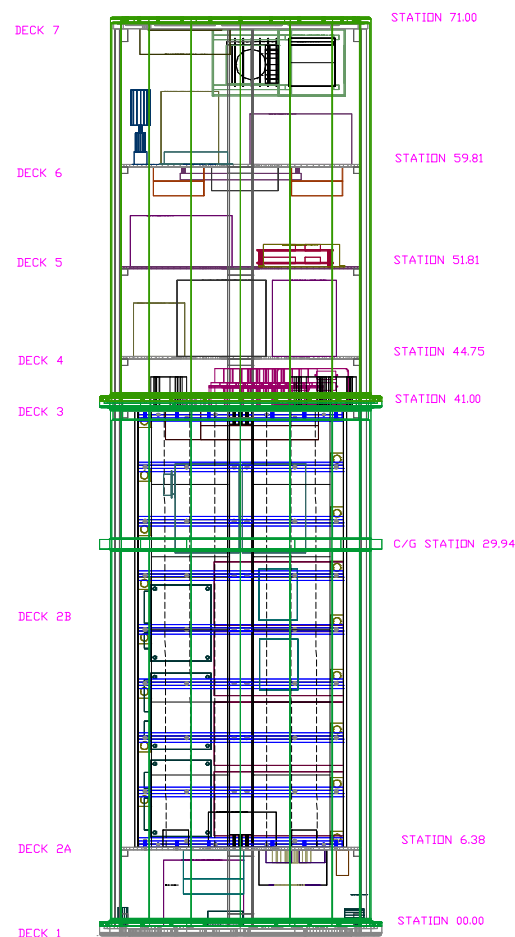


- **CDM Design**

- 2 Aluminum outer skins with bulkheads on both ends.
- O-ring seals on both ends and middle are made of Butyl rubber. Butyl is functional to  $-70^{\circ}\text{C}$  and less permeable than Viton.
- Electrical interface through hermetic connectors on Bulkhead Deck #1, Butyl O-rings used.
- Gas makeup system using carbon composite storage bottle controls pressure from 10 to 15 psi absolute.
- Bulkhead Deck #7 attached to longerons with floating fasteners to compensate for thermal expansion of skin.
- 5 Circulating fans with 4 modes of control. On/ Off/ Thermostat Enable/ Disable.

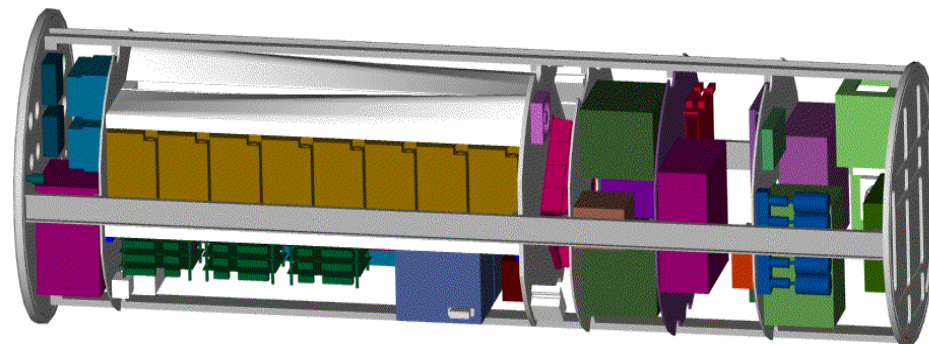


# CDM Design

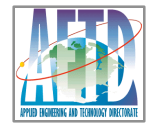
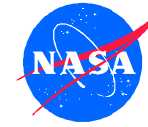


## • Mass Properties

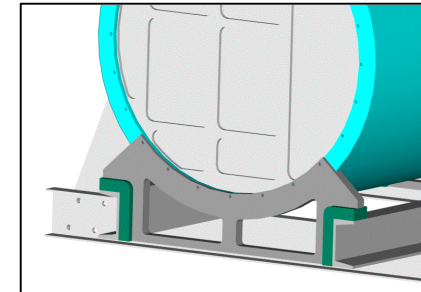
- Weight: 620 lbs.
- Height: 71.375 inches
- Tube Diameter: 20.44 inches
- Joint Diameter: 22.25
- C/G from Sta.0: 29.94 inches
- Pitch-Yaw MOI: 50.3 Slug-Ft<sup>2</sup>



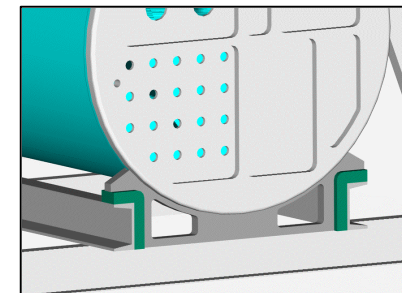
# *CDM Cradle, Gondola Mount*



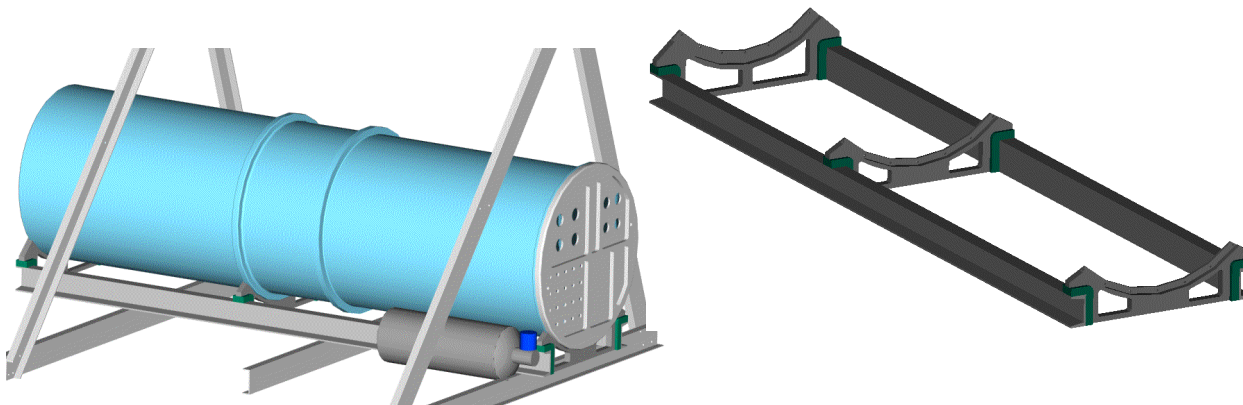
- Cradles Mounted to CDM at Joints
- Mounted to Gondola w/6 Bolts (3/8 160ksi)
- Cradles and Channel Support – Alum.
- Fiberglass Insulators.
- Support slotted 0.3” for thermal expansion.



**Forward Cradle**



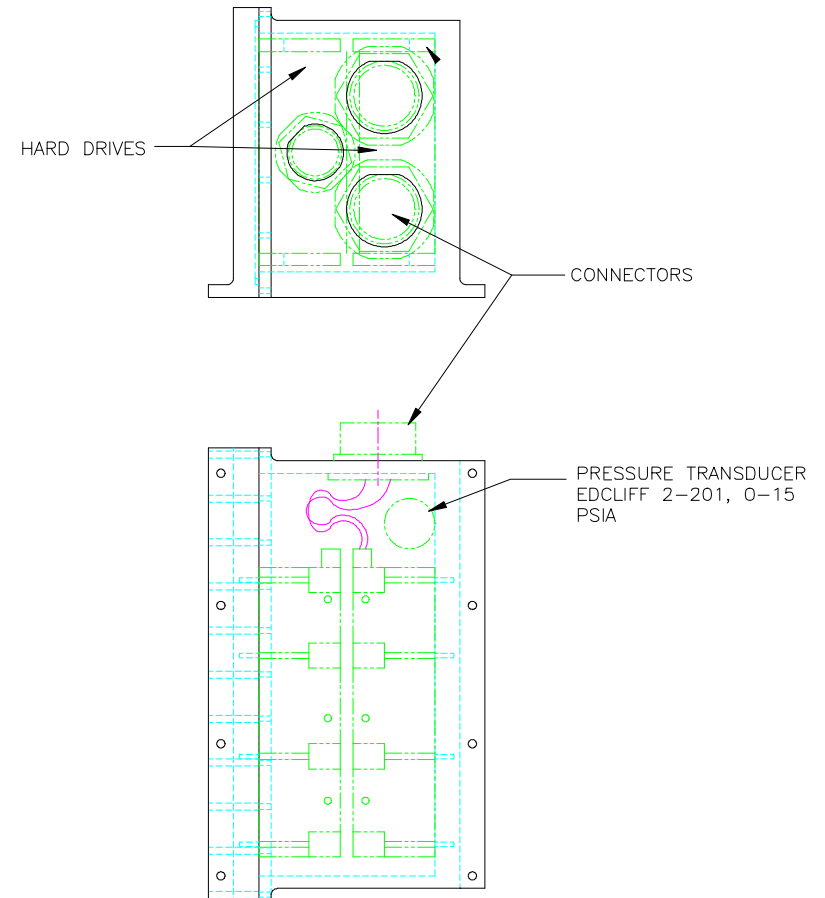
**Aft Cradle**



# Hard Drive Enclosure



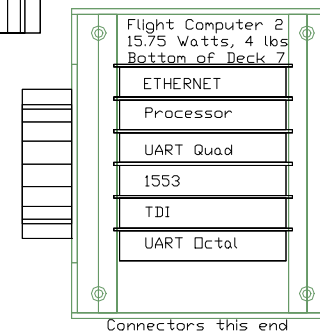
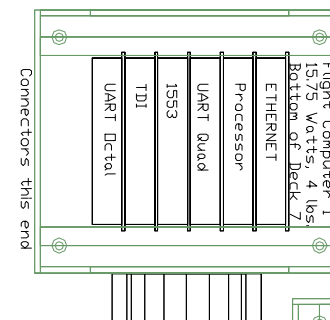
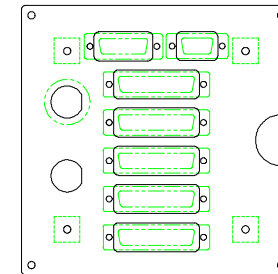
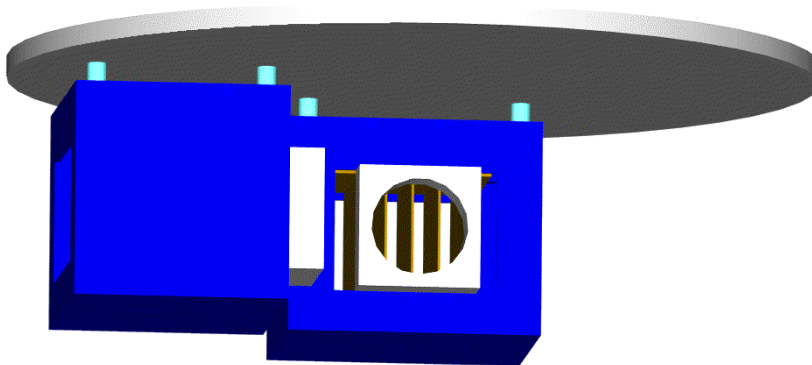
- Enclosure houses 2 ea. 40 gigabyte HD.
- O-ring seals are Butyl B0612-70.
- Thermostatically controlled heater.
- Pressure Transducer.
- Enclosure located on Deck 6 of CDM.

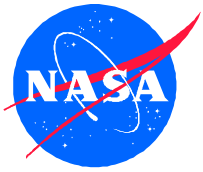


# Flight Computers



- 2 Flight Computer Enclosures
- PC104 Form Factor, 486 Processors
- Located on CDM Bulkhead Deck #7.
- Mounted with delrin standoffs, thermal.
- Fan cooled, 21 cfm, .8 watts.





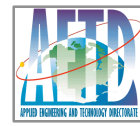
**ULDB  
Mech.  
Systems  
Design  
Review**

**3.9  
Enclosures  
and  
Gas Makeup**

Bob Ray  
Code 546.w  
July 10, 2000

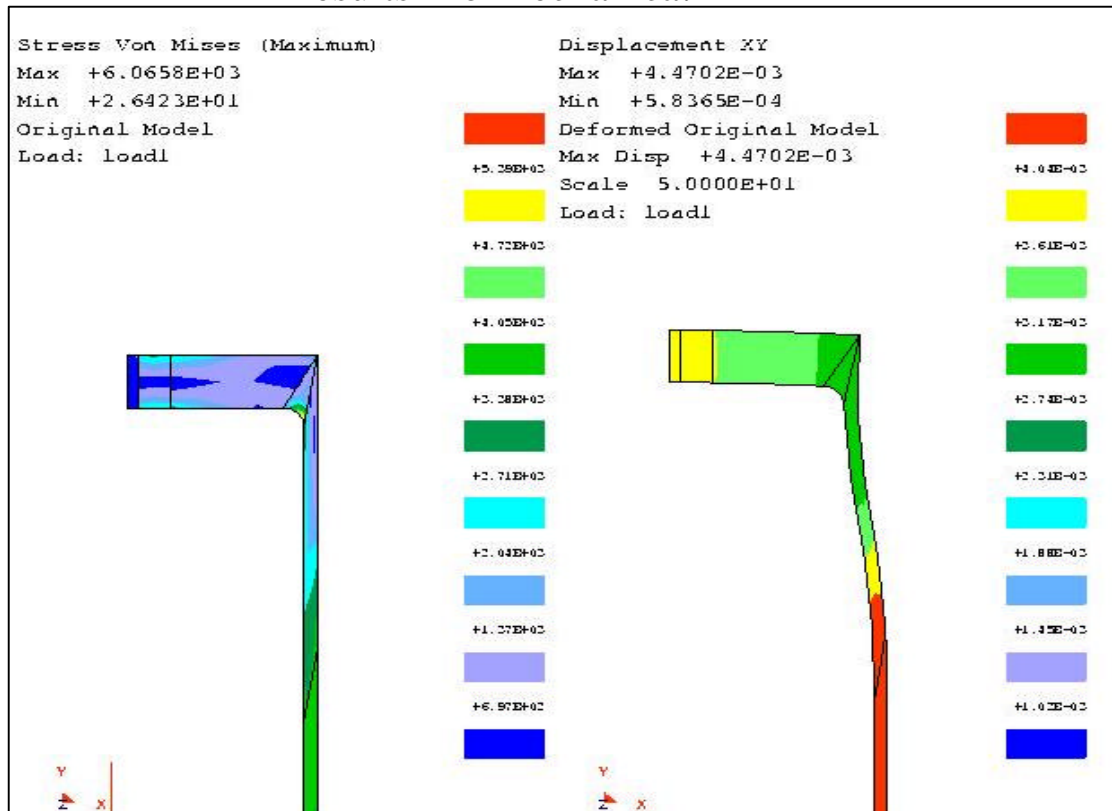
# *Enclosures Static Structural Analysis*

# CDM – Structural Analysis



- Top Lip Forward Skin, 30 psi differential pressure.
  - Safety Factor 6:1

## Results Pro Mechanica:



Comparative Hoop Stress  
based on Roark 6<sup>th</sup> Edition:

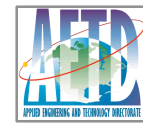
$$\text{Hoop Stress} = PR/T$$

$$30 * 10.12 / .08 = 3800 \text{ psi}$$

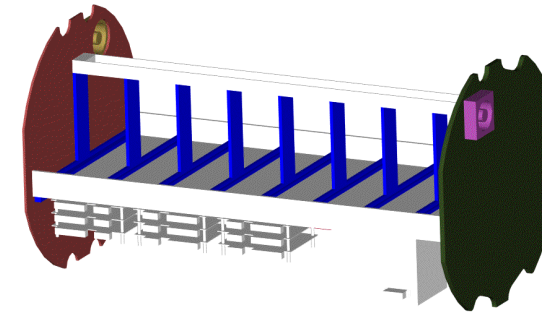
$$\text{Radial Displacement} = PR^2/ET$$

$$30 * 10.12^2 / 9E6 * .08 = .0043 \text{ in.}$$

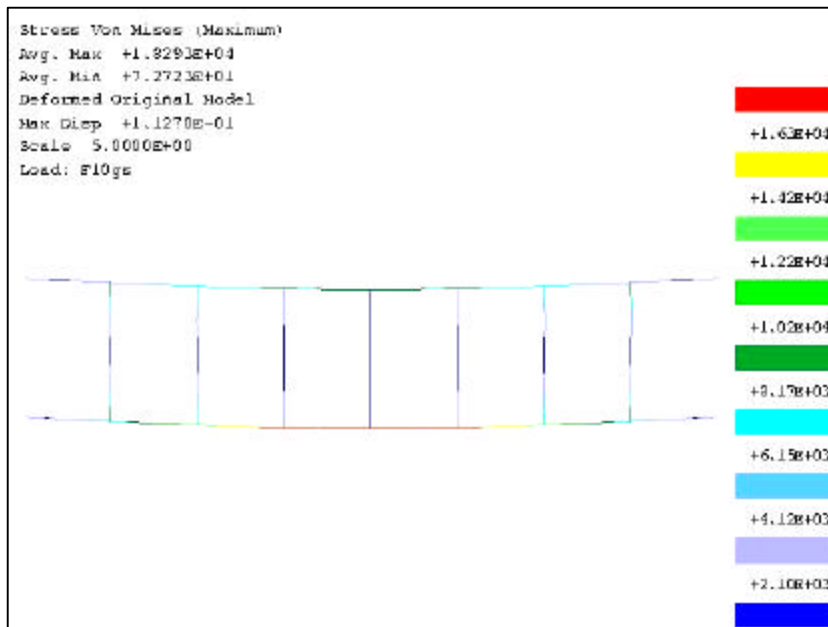
# CDM – Structural Analysis



- Deck 2B, Battery Deck
  - 10G Load, batteries + components
  - Safety factor 2



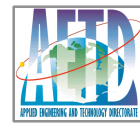
## Results Pro Mechanical:



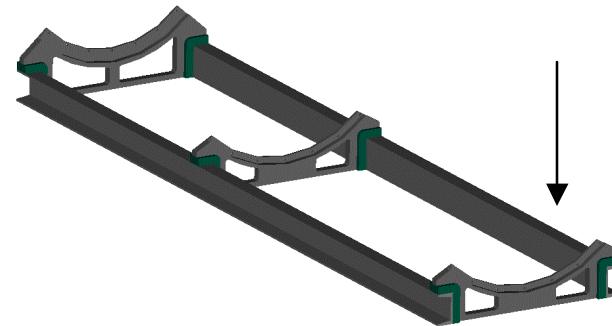
## Comparative Hand Calculations

|                                    |                         |
|------------------------------------|-------------------------|
| Composite MOI:                     | $I=.963$                |
| Neutral axis to extreme:           | $Y=1.375''$             |
| Section Modulus (I/Y):             | $Z=.700$                |
| Uniform Load                       | $W=3420$                |
| Beam Length                        | $L=34$                  |
| Max Stress = $WL/8Z$               | $= 20,764 \text{ psi}$  |
| Max Deflection = $5/384 * WL^3/EI$ | $= .182 \text{ inches}$ |

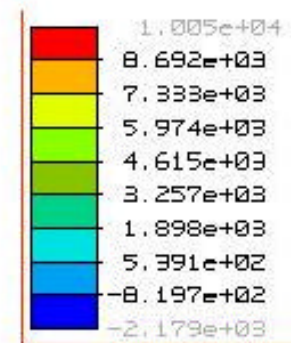
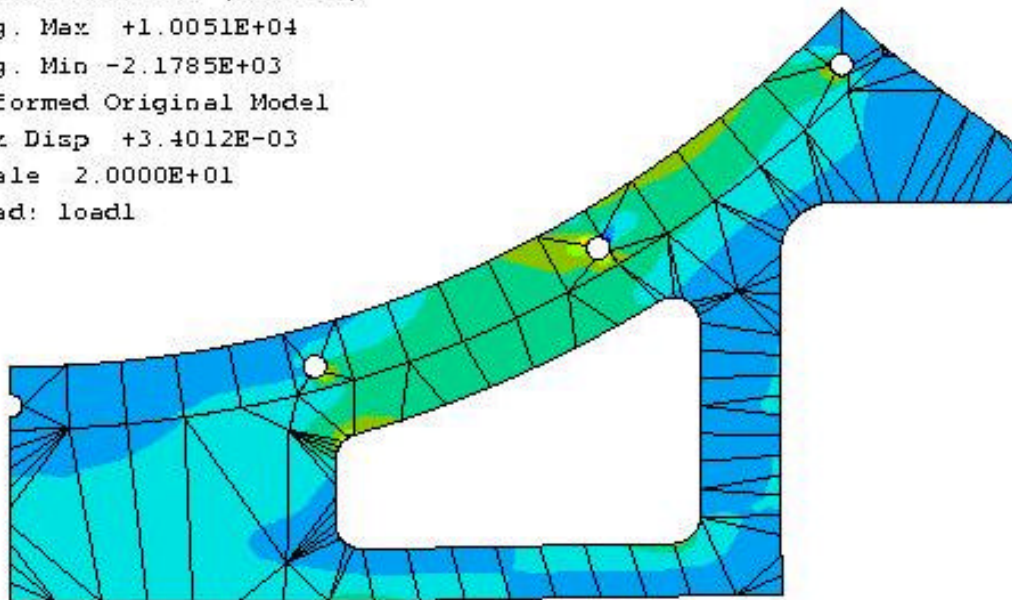
# CDM – Structural Analysis



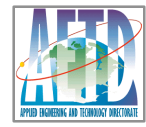
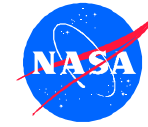
- CDM Aft Cradle, 10G Load
  - 6061-T6 Aluminum
  - Safety Factor 3.7



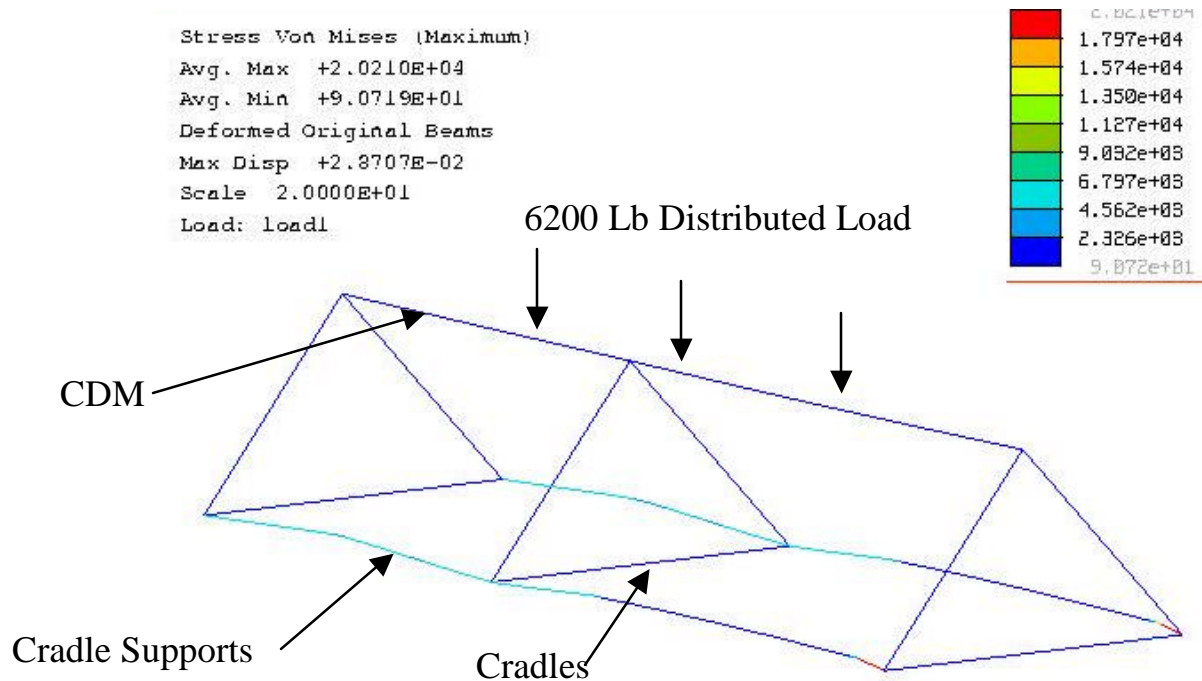
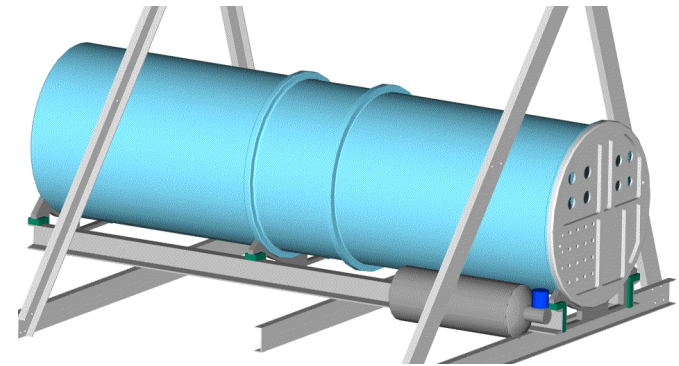
Stress Max Prin (Maximum)  
Avg. Max +1.0051E+04  
Avg. Min -2.1785E+03  
Deformed Original Model  
Max Disp +3.4012E-03  
Scale 2.0000E+01  
Load: load1



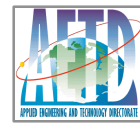
# CDM – Structural Analysis



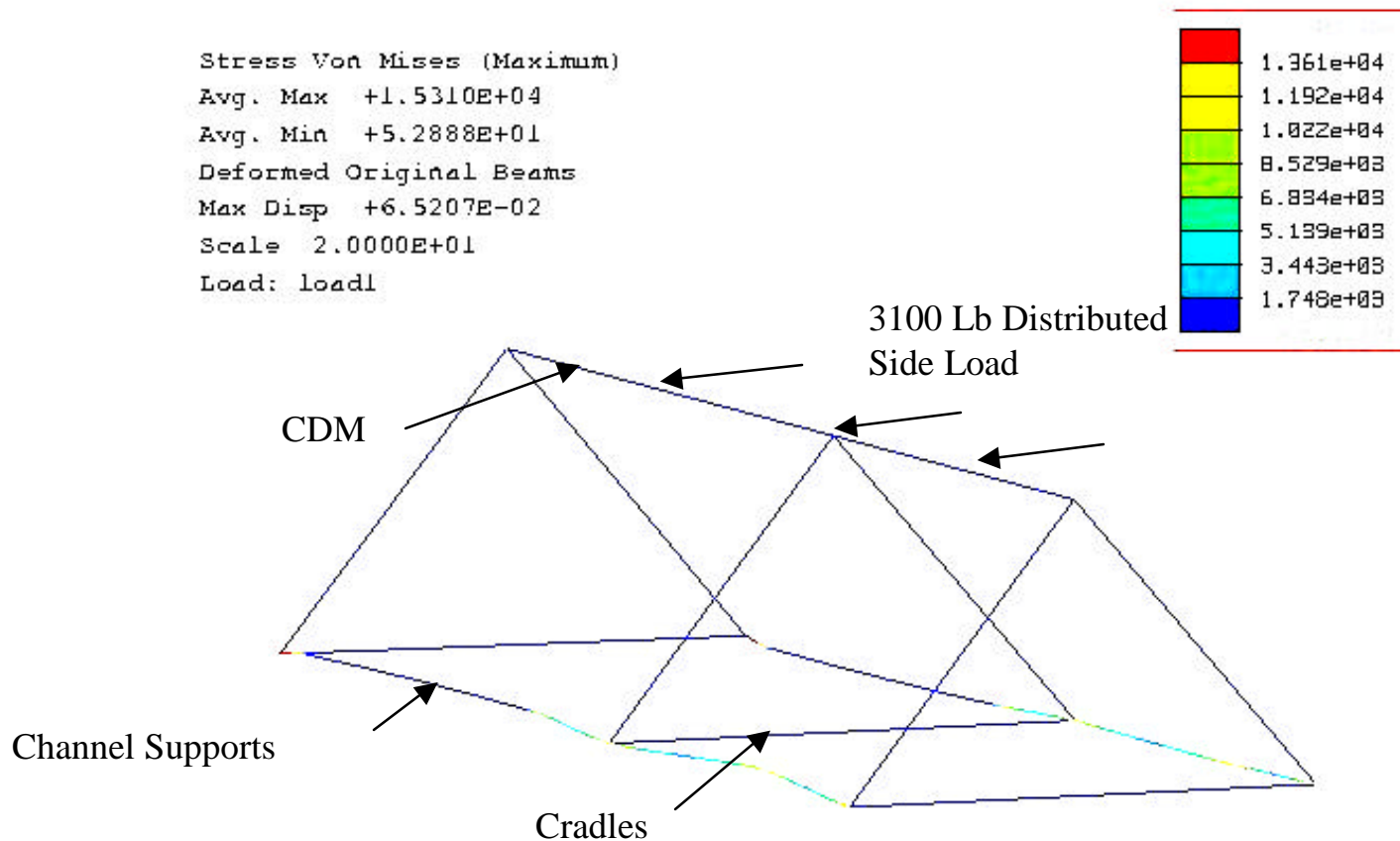
- CDM Cradle Support, 10G Load
  - 6061-T6 Aluminum 3” C-Channel
  - Safety Factor 1.8



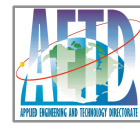
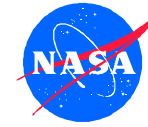
# CDM – Structural Analysis



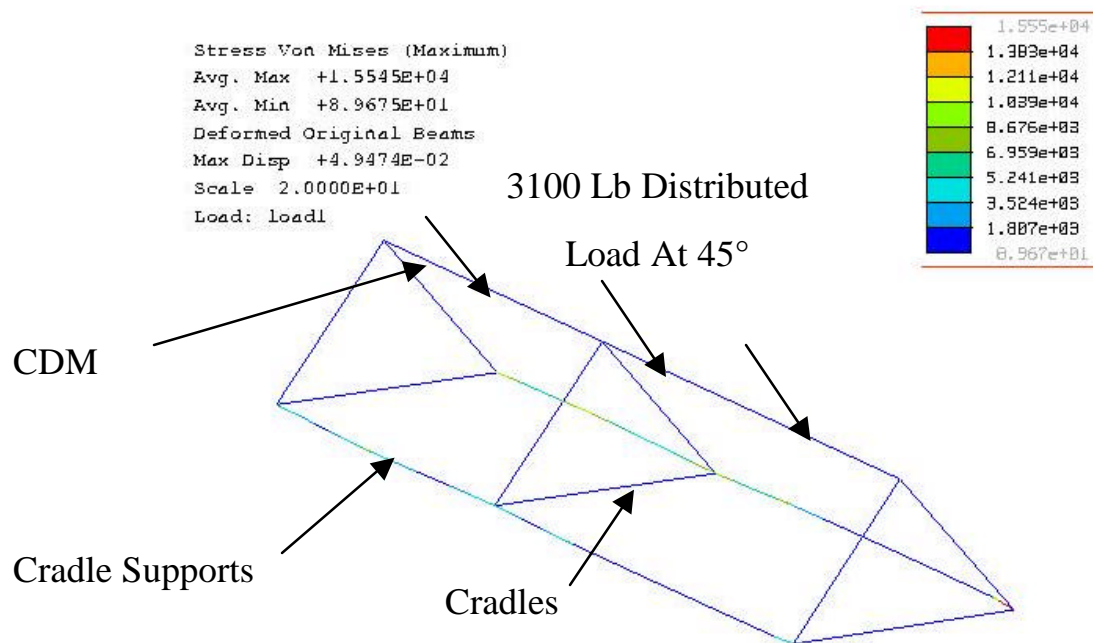
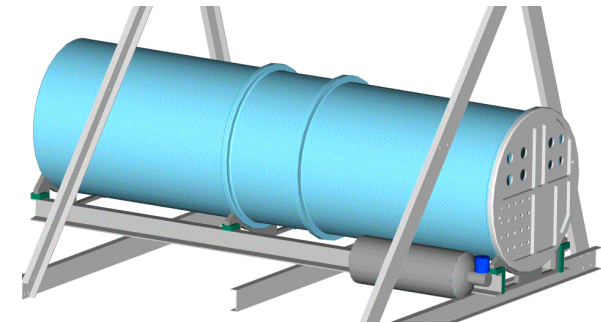
- CDM Cradle Support, 5G Side Load
  - Safety Factor 2.4



# CDM Structural Analysis

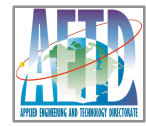
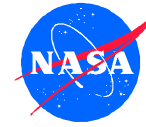


- **CDM Cradle Support, 5G Load @ 45°**
  - 6061-T6 Aluminum 3" C-Channel
  - Safety Factor 2.3

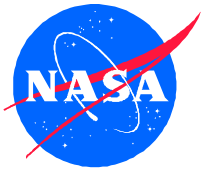


# *Fastener Analysis*

---



- **CDM To Gondola**
  - 6 each 5/16 bolts, 100 ksi shear, .058 stress area
  - 5G total load = 3100 lbs, per bolt = 516 lbs
  - Per bolt stress = 9 ksi., Safety Factor 10
- **CDM Longerons to Aft Bulkhead**
  - 4 each #8 screws, 100 ksi shear, .0147 stress area
  - 10G total load = 1800 lbs, per bolt = 450 lbs
  - Per bolt stress = 31 ksi., Safety Factor 3
- **CDM Pressure Bulkheads**
  - 24 each #10 screws, 160 ksi tension, .02 stress area
  - $15 \text{ psi} \times 322 \text{ in}^2 = 4830 \text{ lbs}$  , per bolt = 200 lbs
  - Per bolt stress = 10 ksi., Safety Factor 16



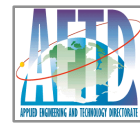
**ULDB  
Mech.  
Systems  
Design  
Review**

**3.9  
Enclosures  
and  
Gas Makeup**

**Bob Ray  
Code 546.w  
July 10, 2000**

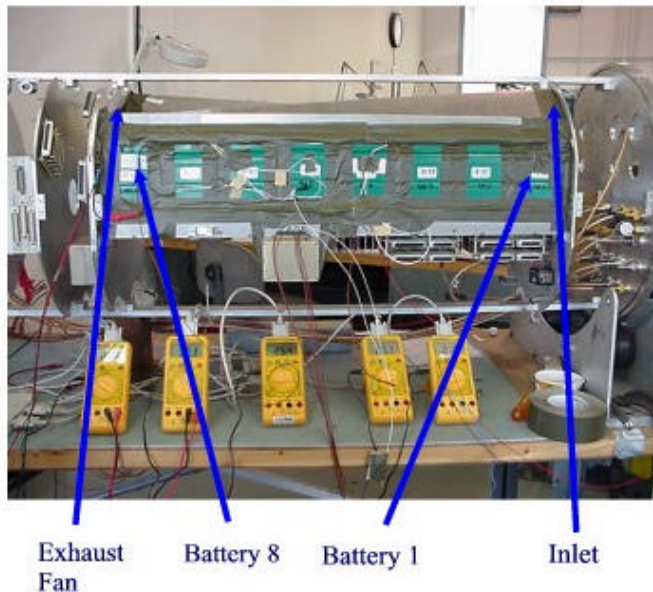
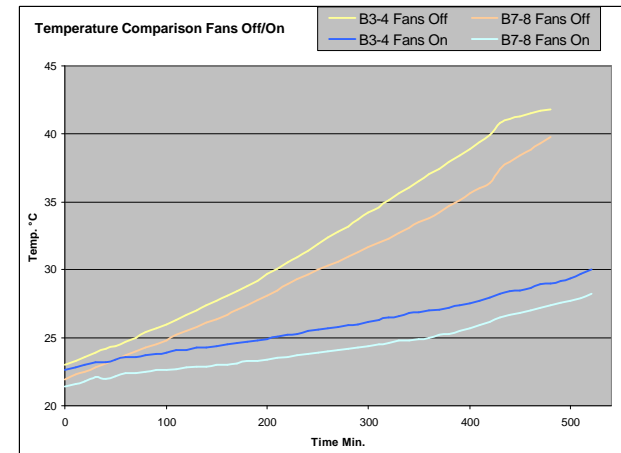
# *Enclosure Design Validation Testing*

# CDM – Design Validation Testing

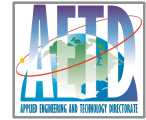
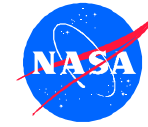


## •Battery Fan Characterization

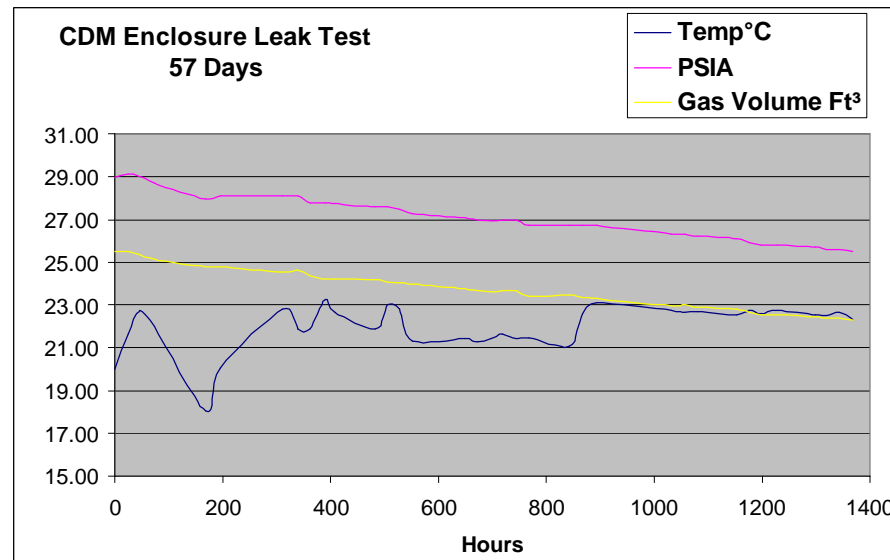
- Test 1: Fans off – full charge cycle.
- Test 2: Fans on – full charge cycle.
- Both tests at ambient room temp.
- Results applied to thermal model.



# CDM – Design Validation Testing

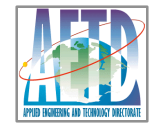
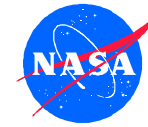


- **CDM Enclosure Long Duration Leak Test**
  - Pressurized to 29 psi absolute.
  - Test performed at room temperature.
  - Test Duration 57 days
  - Total volume loss 12.6%
  - Average leak flow factor .0006 Cv

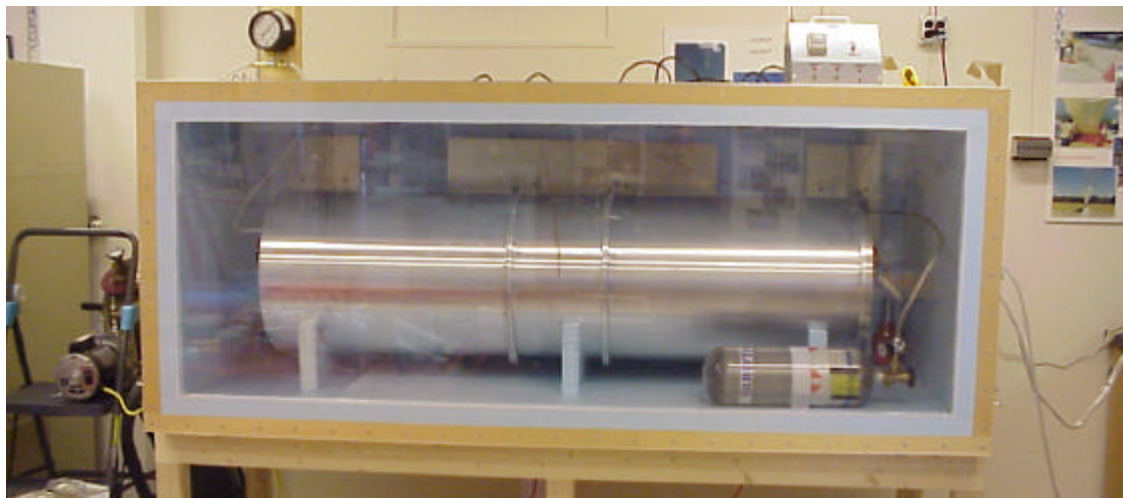


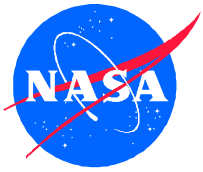
# *CDM – Design Validation Testing*

---



- **CDM Thermal Cycle Leak Check**
  - Five thermal cycles from +50° to –50°C
  - Test performed without component heaters.
  - Internal start pressure was 14.5 psig @ +50°C
  - Duration 3 days, ending pressure 14.25 @ +50°C
  - Total volume loss 1.7%. (Long duration test after 3 days was 1.5%.)





**ULDB  
Mech.  
Systems  
Design  
Review**

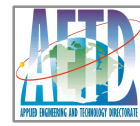
**3.9  
Enclosures  
and  
Gas Makeup**

Bob Ray  
Code 546.w  
July 10, 2000

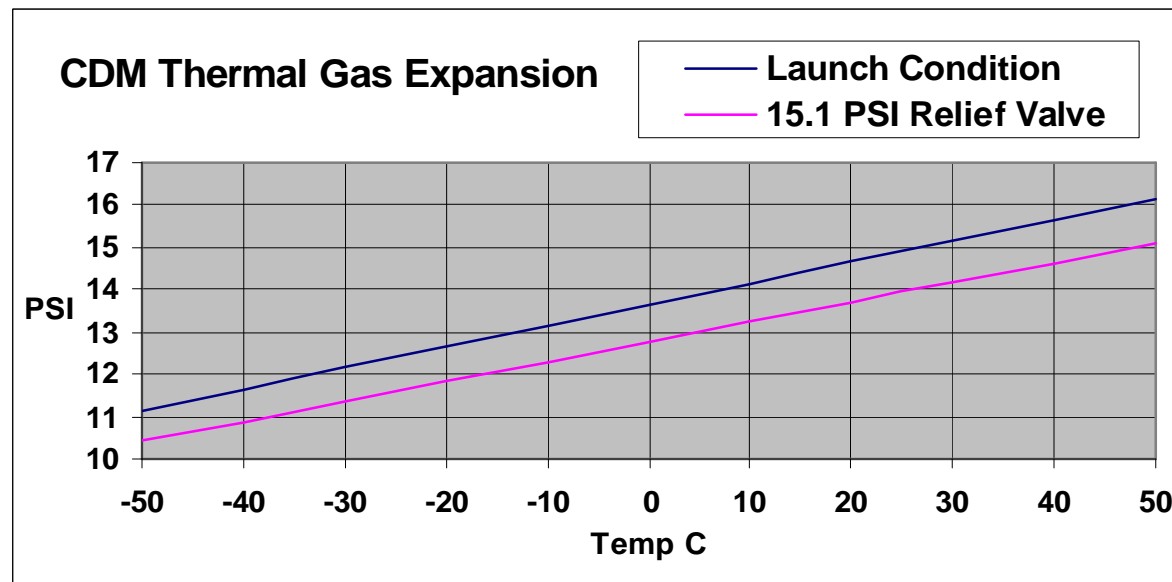
## *Gas Makeup System*

- Functional Requirements
- Design
- Validation Testing

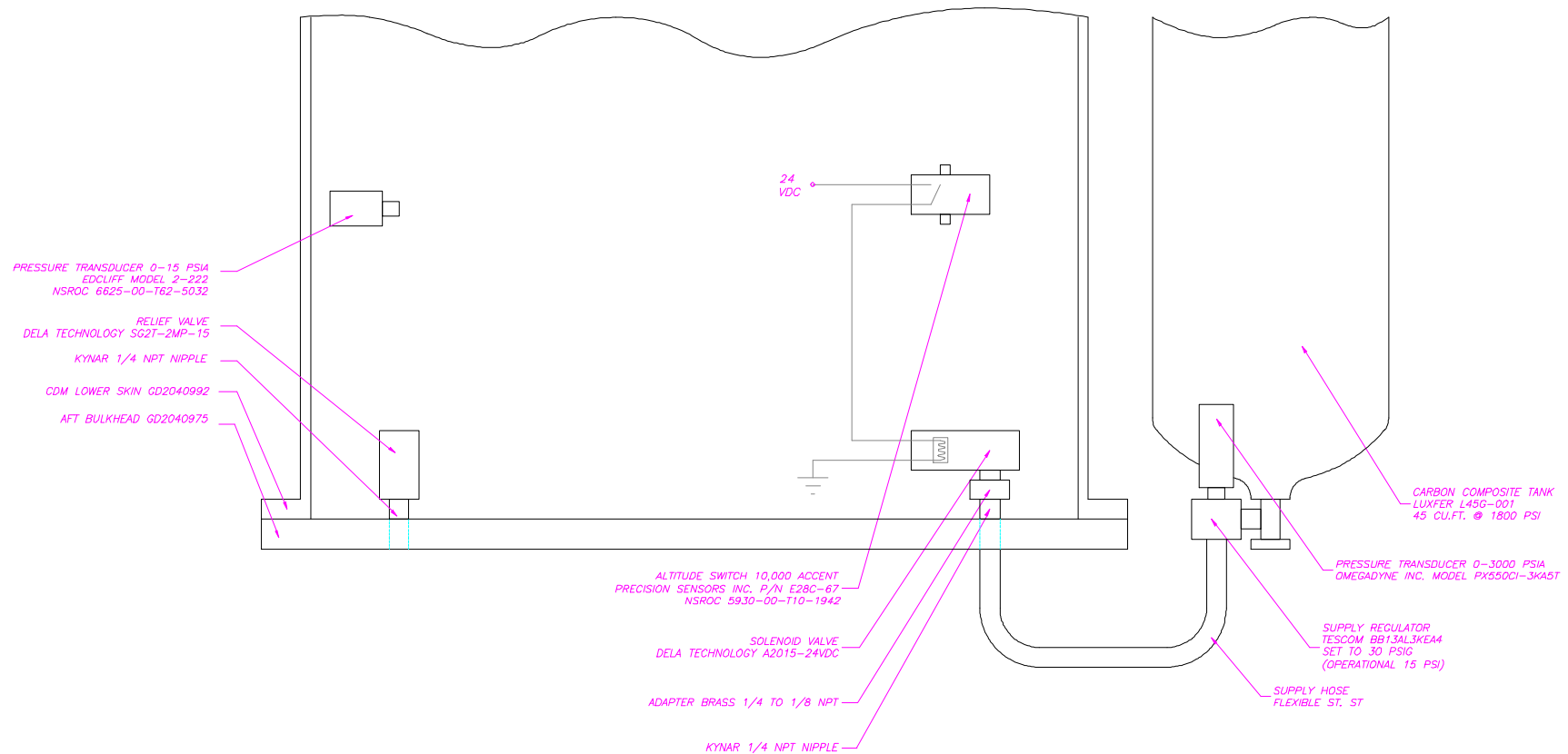
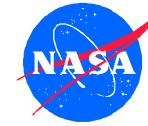
# Gas Makeup System



- **Gas Makeup System Functional Requirements**
  - No day/night cycle makeup gas usage from thermal expansion and contraction.
  - Control pressure range from 10 to 15 psi absolute.

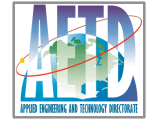
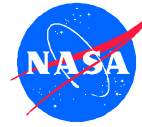


# Gas Makeup System Design



# *Gas Makeup System Design*

---



- **Gas Flow Factors, Cv (ft<sup>3</sup>/min x delta pressure)**
  - Supply Regulator .06
  - Solenoid Valve .17
  - Relief Valves (2) .40
- **Flight Pressure Settings**
  - Supply Regulator
    - Set to 45 psig @ +22°C pre-flight
    - At 120,000 ft. : 35 psi @ -50°C, 26 psi @ +50°C
  - Pressure Switch 10.1 psia (precision 10,000 ft. alt. sw.)
    - Activation Tolerance 9.72 to 10.5 psia
    - Deactivation Tolerance 10.5 to 11.1 psia
  - Relief Valves 15 psi (differential)
- **Gas Volume:** Storage Tank = 40 ft.<sup>3</sup>, CDM ~ 6 ft.<sup>3</sup>

# Gas Makeup Testing



- **Thermal/Vacuum Component Test**

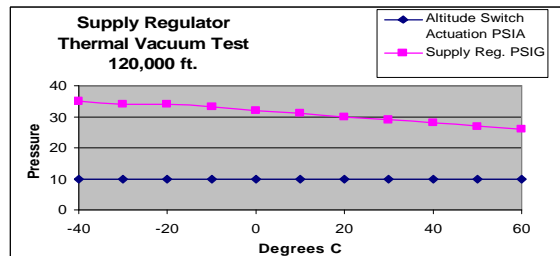


Chart shows effects of temperature and altitude on supply regulator outlet pressure and altitude switch. Regulator was set to 45psi @ 22°C.

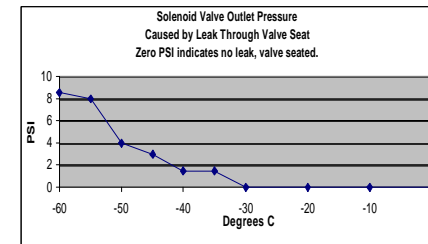


Chart shows effects of temperature on solenoid valve seat. Pressure is measured on down stream side of solenoid, low volume. Pressure backup indicates valve seat is leaking.

- **CDM Thermal System Test**

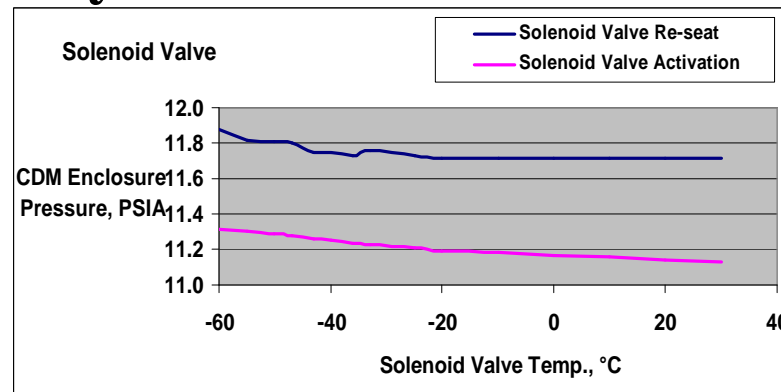
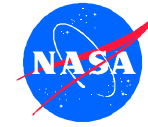


Chart shows effects of temperature on system.

# *Risk Assessment & Mitigation*

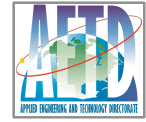
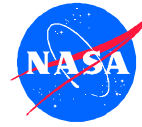
---



- Pressure loss due to seal failure, gas makeup system failure.
  - **Risk:** Loss of pressure control and convection thermal control.
  - **Mitigation/Reliability:** Hard Drives will be sealed in the hard drive enclosure, inside the CDM, redundant enclosures. Seal failure in the CDM alone will not cause pressure loss if leak is less than .5 in<sup>3</sup>/min (.0045 Cv). The gas makeup system can keep up with the leak. Design optimization through thermal analysis, pressure testing, thermal vacuum testing, and test flight from Alice Springs, 2000.
- Structural failure from over-pressure caused by gas expansion or regulator failure.
  - **Risk:** Structural failure due to over-pressure leads to loss of thermal control and structural failure.
  - **Mitigation/Reliability:** Redundant 15 psi relief valves. One on each bulkhead. Thermal vacuum testing, and test flight from Alice Springs, 2000.
- Fan failure
  - **Risk:** Loss of thermal control
  - **Mitigation/Reliability:** Each Flight Computer has a fan, redundant flight computers. There are 2 fans, intake and exhaust, to cool the batteries. Loss of one fan will reduce efficiency, loss of both will reduce allowable charging time. One additional fan is located on deck 5. Thermal vacuum testing, and test flight from Alice Springs, 2000.

# *Documentation*

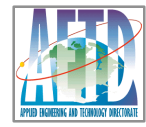
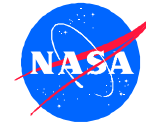
---



- **Project records for Enclosures & Gas Makeup**
  - Located in 456.w Branch Office
    - Enclosures Implementation Plan ULDB/TIGER-3.9.2
    - Gas Makeup Implementation Plan ULDB/TIGER-3.9.3
  - Located in Building C-15
    - CDM Enclosure Assembly and Test WOA # ULDB/TIGER-3.9.2
      - Flight Fasteners RITS/WOA List
      - Fabricated Parts WOA List
        - Drawing Configuration Control: [\\Wal2\Drawings\ULDB](#)
      - Outside Vendor Parts RITS/WOA List
      - Component Characterization Sheet
      - CDM/Gas Makeup Assembly Procedures
      - CDM/Gas Makeup Test Plan
  - Located on ULDB/TIGER Project Resources Web
    - Enclosures Interface Control Doc. 3.9.2
    - Gas Makeup Interface Control Doc. 3.9.3

# *Australia Integration Testing*

---



- Enclosures
  - Thermal vacuum test of assembled Hard Drive Enclosure
  - Leak Test of sealed, assembled CDM
  - Thermal test of assembled CDM
- Gas Makeup
  - System Test with assembled CDM

# *Status of Australia Test Flight*

---



- Enclosures
  - Command Data Module
    - All parts fabricated except CDM Support Cradle.
    - Design validation testing complete.
    - Integration testing proceeding on schedule.
  - Hard Drive Enclosure
    - Fabrication complete
    - Integration testing proceeding on schedule.
- Gas Makeup
  - Design validation testing complete.
  - Integration testing proceeding on schedule.

# Schedule

